occur for the Eldorado Mountain site for the Boulder area. For a transmitter location on Eldorado Mountain, many locations throughout the Boulder area (including the DOC Laboratories and the Table Mountain NRQZ) exhibit LOS paths. The ability of the simple free-space calculation given in equation (2) to predict E-field strengths in a LOS situation is illustrated in figures 11 and 12. These figures show the measured E-field strengths for a transmitter located on Eldorado Mountain for the DOC Laboratories and the Table Mountain NRQZ. Notice that the free-space calculation correlates very well with the measured data. There is some variability in the measured data, due to multipath effects that the free-space model cannot account for, but typical E-field strengths at both sites are very well accounted for with the free-space model.

Thus, once the actual antenna patterns are known, the EIRP in any direction can be obtained, and equation (2) can be used to estimate the E-field strengths in the LOS situation. An alternative approach is to simply scale the results in this report by the appropriate EIRP for an antenna at a given location and a given direction. From the results in figure 12, it is seen that, for a transmitter on Eldorado Mountain, a reduction of 23 dB in either the transmitter power level or in the antenna gain is needed to achieve the FCC NRQZ limit.

8. EFFECTS OF BROADBAND TRANSMISSION ON SENSITIVE MEASUREMENTS

Historically, the radio science programs in the former National Bureau of Standards (those programs are now in NIST and ITS) drove the need to establish a field site remote from their Washington, DC, laboratories. Boulder was chosen over several contenders because of the relatively quiet radio-frequency electromagnetic environment, which would allow for more accurate measurements and experiments; the varied geographic terrain, which would facilitate the study of radio propagation; and the presence of a major university (the University of Colorado) as well as the proximity of a large city (Denver). The technical mission of the Boulder labs was to develop the most accurate possible reference standards and calibration services to insure compatibility of the emerging radio, microwave, and radar technologies that the nation was then developing. Radio propagation research was fundamental to this work, and as higher frequencies were explored, the interactions between electromagnetic waves and atmospheric layers led to new directions of research. This work was, and continues to be, fundamental to all of the advances made in radio-frequency technology. NIST's research on accurate measurement systems, and its development of standards and calibration services for the Nation, play an essential role in making possible the technologies that we use daily such as wireless communication, high-speed digital technology, time-and-frequency synchronization, satellite communications, radar, and optical fiber communications links, to name only a few.

Radio research projects performed outdoors often require that receivers be constructed to receive wideband signals. Furthermore, those receivers must often be constructed with high performance, low noise amplifiers (LNAs) in the so-called front-end, just after the receive antenna. The requirement for wide bandwidth means that such receivers integrate the total energy across a wide part of the spectrum. The LNAs used in those front ends are susceptible to nonlinear effects due to the integration of large amounts of energy across wide portions of spectrum. This effect has been documented in Reference [30]. Simply put, a wideband radio receiver with a sensitive amplifier in the front end will experience a condition known as overload in the presence of strong signals that are not only present at the desired frequency, but that are also substantially off-tuned from the center frequency. Overload of LNAs can occur in the presence of strong signals even if those signals are as much as a few hundred megahertz off the receiver's center frequency [30]. When an LNA goes into an overload condition, its gain is greatly reduced. The result is loss of the desired signal or signals.

Because of the Government's need to be able to perform radio research in outdoor locations with wideband, sensitive receivers, the only practical and general technical solution is to limit the total power originating from local signal sources. The limitation must be adequate to ensure that the cumulative (integrated) amount of energy that is coupled into the sensitive front end amplifiers from all local signals is low enough not to overload the receiver front ends. This is one requirement that has caused the Federal Government to create and maintain the Table Mountain NRQZ.

The grandfathered signal levels of television channels 4, 6, 7, and 9 provide an example of the difficulties that high signal strengths within the NRQZ produce for sensitive radio measurement systems. These grandfathered signal levels within the NRQZ range from about 3 dB above the limit to as much as 13 dB above the limit. When the spectrum survey in this report was performed, it was necessary to insert 10 dB of attenuation into the measurement system's front end to prevent overload by these television signals. That is, the sensitivity of the entire measurement system had to be degraded by 10 dB to prevent saturation due to these signals. This attenuation had to be inserted for all measurements in the television bands between 50 MHz and 88 MHz (due to strong E-fields from channels 4 and 6), and also between 170 MHz and 220 MHz (due to E-fields from channels 7 and 9). Signal strengths below the NRQZ limits usually require no attenuation in the receiver system front end, and enable more sensitive and more accurate measurements.

Similar measurement degradation will impair the usefulness of measurements and experiments in other bands, to the extent that signals in those bands exceed the NRQZ limits. Mobile signals that exceed the NRQZ limits may provide some technical opportunities for ameliorative work-arounds, but broadcast signals that are effectively present on a continuous basis do not allow such work-arounds. Receivers in those bands are permanently impaired by the incident signals, as happened for the horizontally polarized spectrum survey measurements described above. This integrating effect of several frequencies transmitting simultaneously has adverse effects on several types of research measurement efforts that occur at both the Table Mountain NRQZ and at the DOC Laboratories.

There are no Federal, state, or local laws or regulations, corresponding to the NRQZ restrictions, that protect the DOC Laboratories. However, the level of EM-field emissions from the proposed towers may be high enough on-site to compromise some experimental and metrological programs. The E-field strengths from a single station transmitting at 1 MW EIRP from Eldorado Mountain will result in 0.5 V/m to 1 V/m over the entire site. To date, six stations have been given permission to operate at 1.6 MW EIRP, which, upon scaling the results above to the 1.6 MW EIRP level, results in an E-field-strength on-site of 0.6 V/m to 1.3 V/m. Furthermore, the potential tower operators are soliciting existing TV and FM stations to move their transmitters to the Eldorado Mountain site. Such a concentration of transmitters will have a more adverse effect because of the even broader spectral coverage. Cutting-edge physics, metrology, and radio research conducted at the DOC Laboratories for the benefit of industry and the Nation could be compromised. Some examples of programs sensitive to electromagnetic fields are given below.

The research and antenna calibrations conducted at the NIST Open Area Test Site (OATS) groundscreen facility is critical for support of a very broad cross section of industry. Literally the entire U.S. electronics industry, including all manufacturers of computer and information technology, communications equipment, medical electronic equipment, electronic test equipment, television and other electronic entertainment equipment, certain appliances, industrial equipment, and many other categories, must test their product's conformity to national and international standards. To be recognized, these tests must be traceable to NIST, and the standards themselves are developed in an international forum with NIST providing the technical expertise and experimental validation to advance the cause of U.S. industry. All tests and calibrations, and experimental research performed on the groundscreen are performed from 30 MHz to 1 GHz, and the DTV bands will cover a significant portion of this band (476 MHz to 698 MHz). The comparatively strong field strengths from the DTV towers (on Eldorado Mountain) will literally override the signals that NIST generates and uses in its calibrations and experiments. Furthermore, the broad nature of the signals is such that it will not be possible to shift to an adjacent null in the spectrum and obtain an approximate measurement. NIST research that supports ANSI, ITI, IEC/CISPR, as well as a broad cross section of industry, will be compromised.

Interference problems with DTV signals are currently being experienced by commercial electromagnetic compatibility (EMC) laboratories where EMC measurements and calibrations are performed routinely at other OATS facilities, as indicated by Roland Gubisch [31], the vice-chair of the United States Council of EMC Laboratories (USCEL). USCEL was developed to aid U.S. industry with EMC standards and testing procedures. Gubisch indicated [31] that DTV signals have had adverse effects on an OATS in the Boston, Massachusetts, area. At this OATS and other sites, field strengths as low as 0.0002 V/m (46 dBμV/m) have interfered with tests. The 0.0002 V/m is the FCC radiated emission limit for unintentional radiators [32]. The DTV signals act as 6 MHz wideband noise in the 500 MHz to 700 MHz frequency range, hindering the ability to test and certify electronic products on these outdoor sites. The broadband noise nature of the 6 MHz DTV signals can be seen in the 2001 spectrum survey for the DTV Channel 32 (578 MHz to 584 MHz) transmission, see figure A.41. In fact, Gubisch has informed NIST that USCEL members have experienced problems on outdoor facilities when DTV E-field levels are even lower than 0.0002 V/m. The broad 6 MHz signals from each station and the even broader spectrum saturation from strings of adjacent channels are preventing EMC test laboratories from making measurements in outdoor facilities that are prescribed by international standards. This is forcing commercial labs to use much more costly and potentially less accurate special indoor facilities such as semi-anechoic chambers. However, NIST as the national standards laboratory that provides the basis for and harmonization of all national measurements, must maintain the smallest uncertainties possible in its measurements.

Other examples of the types of interference that would be experienced at the DOC Laboratories are as follows. In order to simulate potential effects of instrumentation of the proposed DTV towers on Eldorado Mountain, experiments were performed in two different laboratories at NIST. In these experiments E-field strengths of 0.1 V/m, 0.5 V/m, and 1.0 V/m (the values that would be present at the DOC Laboratories as discussed above) were generated in two different research laboratories. The first laboratory was in the Optoelectronics Division, the Sources and Detectors Group. This group is developing standards and measurement systems for optical intensity noise of laser transmitters and optical fiber amplifiers used in optical communications systems. These consist of both laboratory and transfer standards. In the study, E-field strengths of 0.1 V/m, 0.5 V/m, and 1.0 V/m were radiated onto optical noise instrumentation at frequencies of 400 MHz to 700 MHz. This frequency range falls within the broad frequency range of interest for noise studies, which presently is 100 MHz to 4.1 GHz and higher. For field strengths of 0.1 V/m, the noise floor of the instrumentation rose between 7 dBm/Hz and 10 dBm/Hz within this frequency range, a significant amount. At field strengths of 0.5 V/m the noise floor rose by 15 dBm/Hz to 33 dBm/Hz, a large and disturbing amount. At field strengths of 1 V/m the noise floor rose by 22 dBm/Hz to 43 dBm/Hz, a significant amount. Without additional shielding of the affected equipment, the resultant increase in the noise floor would prevent NIST from performing low intensity noise measurements, in this frequency range, that are important in noise studies. Presently, it is not known how well additional shielding would diminish this problem. Such a result can only be determined experimentally.

The second experiment was performed in the Time and Frequency Division of NIST. In this division, the Atomic Standards Group, Network Synchronization Group, and Time and Frequency Service Group use GPS signals for the following: (1) to contribute the NIST clock (frequency standards) data to the computation of TAI (International Atomic Time) and UTC (Coordinated Universal Time), (2) to compare UTC as realized at NIST, to the frequency standards of other remote laboratories (such as the U.S. Naval Observatory, the National Physical Laboratory of the United Kingdom, the Physikalisch-Technische Bundesanstalt in Braunschweig, Germany, etc.), and (3) to provide time and frequency dissemination/calibration service to industry and research institutions. In the study, E-field strengths of 0.1 V/m and 0.5 V/m at 613.8 MHz and 787.7 MHz were incident onto the antennas for three different types of GPS receivers. The antennas were located on the roof of the main building at the DOC Laboratories, see figure 80. This figure also illustrates the LOS path that would be present from the Eldorado Mountain tower site. These two frequencies correspond to the first subharmonic of the GPS L2 (1227.6 MHz) and GPS L1 (1575.42 MHz) frequencies. Due to nonlinearity effects of the GPS receiver's LNA (low noise amplifier), the 613.8 MHz and 787.5 MHz signals at 0.5 V/m saturated the front end of the GPS receiver, resulting in loss of GPS signal lock by the receiver. When the second harmonics of these frequencies were greater than −136 dBm as received by the GPS antennas, the receiver could not lock on the GPS signal. Once the E-field strength was reduced to 0.1 V/m the receiver was able to lock on the GPS signal.

The above examples represent only a sample of possible and likely negative effects of higher levels of ambient electromagnetic fields in this frequency range on DOC Laboratory programs in the Boulder, Colorado, area. Other technical programs at NIST, as well as NOAA and ITS programs, may also be impacted.

9. SUMMARY AND CONCLUSION

In this report, we have analyzed the expected E-field strengths in the Boulder area from two proposed terrestrial DTV transmitter locations, the Eldorado Mountain site and the Squaw Mountain site. The Eldorado Mountain and Squaw Mountain sites were chosen in this study because these two possible sites bound the propagation environment that would occur at both the Table Mountain NRQZ and the DOC Laboratories. The Eldorado Mountain site affords substantial line-of-sight coverage over the Boulder area, and the Squaw Mountain site affords only indirect (diffractive) coverage over the same area. The other possible tower sites fall between these two types of propagation conditions. The proposed transmitter tower heights for the two sites were obtained from either the landowners or public documents.

In this analysis, measurements of the E-field strengths for a transmitter located at each of these sites were performed. These measured data were then compared to predicted E-field strengths obtained from the ITS ITM propagation model. The predicted field strengths from the two transmitter locations matched well with measured strengths from those locations at frequencies near both ends of the existing UHF television band. This indicates that the ITM predictions are reliable, and can be used with confidence in predicting the strengths that might be received at any given location in the area (with the exception of very deep shadowed regions) for any given transmitter and receiver heights.

The ITS ITM propagation model was then used to predict the E-field strengths in the Boulder area for the actual proposed transmitter antenna heights of two possible transmitter locations, Eldorado Mountain and Squaw Mountain. The E-field strengths were calculated based on 1.0 MW EIRP. Once the E-field strengths are obtained for 1.0 MW EIRP, the E-field strengths can be scaled to any desired transmitter power level. With these predictions, we were able to determine the E-field strengths at both the DOC Laboratories and at the Table Mountain NRQZ. The results presented here show that at the Table Mountain NRQZ, the predicted E-field strengths are about 0.3 V/m for a transmitter on Eldorado Mountain at 1.0 MW EIRP. This number exceeds the FCC’s regulatory (47 CFR 73.1030) limit by about an order of magnitude. At that level, the research at the Table Mountain NRQZ will be compromised. The results also show that the E-field strengths at the DOC Laboratories for a transmitter located on Eldorado Mountain are about 1 V/m for 1.0 MW EIRP. These field strengths are high enough to possibly jeopardize the sensitive measurements done on a routine basis at the DOC